No. of Printed Pages : 8 **MPH–012**

M. Sc. (PHYSICS)

(MSCPH)

Term-End Examination

June, 2026

MPH-012 : CONDENSED MATTER PHYSICS

Time : 2 Hours *Maximum Marks : 50*

Note : *(i) Attempt any* ***five*** *questions.*

(ii) You may use a calculator.

(iii) Symbols have their usual meanings.

(iv) Marks for each question are indicated against it.

1. (a) Write down the basis vectors for a body centered cubic (bcc) structure. Calculate its atomic packing fraction. 5

(b) Describe the kinds of interactions that give rise to van der Waals bonding in solids. Explain why the melting point of solid Argon is very low (– 189·4°C). 5

2. (a) The primitive lattice vectors of a direct lattice are :

$$\vec{a}_1 = 2(\hat{j} + \hat{k}); \vec{a}_2 = 2(\hat{k} + \hat{i}); \vec{a}_3 = 2(\hat{i} + \hat{j})$$

Obtain the reciprocal lattice vectors and identify the structure of the reciprocal lattice. 5

(b) Derive an expression for the heat capacity of a solid on the basis of Debye's model. 5

3. (a) Determine the condition governing geometric structure factor for the *fcc* lattice. List *two* missing planes. 5

(b) In the Sommerfeld theory of metals, the wave function and energy for the electron in a cubical box of side L are given by : 5

$$\Psi = \mathrm{N}\exp\left[i\vec{k}\cdot\vec{r}\right]$$

and $$\varepsilon(\vec{k}) = \frac{\hbar^2 k^2}{2m}.$$

Using periodic boundary conditions, derive the energy eigen values. Hence show that the free electron density in a metal can be written as $n = \frac{K_F^3}{3\pi^2}$ where K_F is the Fermi wave vector.

4. (a) For the periodic potential $V(\vec{r}) = V(\vec{r} + \vec{R})$ where $\vec{R}$ are the Bravais lattice vectors, the Bloch wave function is $\Psi_{n\vec{k}}(\vec{r}) = e^{i\vec{k}\cdot\vec{r}}\, U_{n\vec{k}}(\vec{r})$. State the condition on the function $U_{n\vec{k}}(\vec{r})$. Show that $\Psi_{n\vec{k}}(\vec{r} + \vec{R}) = e^{i\vec{k}\cdot\vec{R}}\, \Psi_{n\vec{k}}(\vec{r})$. 4

(b) Show that the Bloch wave function is not an eigen function of the momentum operator. What is the significance of $\vec{k}$ in the Bloch Wave function ? 4

(c) What is the difference between the nearly free electron gas and the tight binding approximation. 2

5. (a) Define the effective mass tensor for a bond energy dispersion function $\varepsilon_n(\vec{k})$. For the energy dispesion relation : 5

$$\varepsilon(\vec{k}) = \frac{\hbar^2}{2m}\left[\frac{kx^2 + ky^2}{3} + k_z^2\right]$$

Calculate the inverse mass tensor. 5

(b) Define and derive the expression for the built-in potential in a *pn* junction as a function of the donor and acceptor concentrations and temperature. You may use the following expressions for the electron and hole concentrations : 5

$$n = n_i \exp\left[\frac{\varepsilon_F - \varepsilon_{Fi}}{k_B T}\right]; \; p = n_{i'} \exp\left[-\left(\frac{\varepsilon_F - \varepsilon_{Fi}}{k_B T}\right)\right]$$

6. (a) What is the piezoelectric effect ? Explain the piezoelectric effect in Barium Titanate. 5

(b) Explain Pauli Paramagnetism that arises from the response of the itinerant electrons in a metal to an external magnetic field. Derive the expression for the Pauli Paramagnetic susceptibility. 5

7. (a) Write down the Heisenberg Hamiltonian for exchange interactions. Explain the different kinds of magnetic ground states possible based on the exchange interactions. 5

(b) What is Meissner effect ? Show that the London equation can explain Meissner effect. 5

8. (a) What are iron-based superconductors ? Give *two* examples of iron based

superconductors. Describe their electrical properties. 5

(b) Explain the significance of energy gap in a superconductor. Calculate the gap energy in Na which has a transition temperature of 3.4 K. Take

$k_B = 1 \cdot 38 \times 10^{-23}$ JK^{-1}. 5

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